EXTENDED ABSTRACT
AHS FORUM 55, MONTREAL, CANADA

Modeling of H-46 Tip Strikes

Greg Zilliac and Kurt Long

Introduction

For over thirty years now, the H-46 Sea Knight tandem rotor helicopter has operated successfully from the decks of various U.S. Navy ships. There have been approximately 210 thousand landings and takeoffs at sea and the vast majority have occurred without incident. Only a small percent of the total H-46 landings and takeoffs have been less than fully satisfactory. On certain ships, (e.g. the LHA amphibious assault ship) the combination of winds at 15 deg. or so off of the bow and low rotor r.p.m. are conditions under which, on occasion, the rear rotor blades have been observed to flap uncontrollably. Cases have been reported where the rotor blades have struck the H-46 sync-shaft cover during startup and shutdown while the H-46 is sitting on the deck. One life has been lost, several people injured and the repair costs total of the 110+ incidents has been estimated to exceed $20 million. To date, the root cause of this problem has not been identified.

Recently, a joint effort by the Navy, NASA and Stanford University has been initiated to study the airwakes of ships and a small part of this effort has been dedicated to H-46 tip strikes. The joint effort includes wind tunnel tests of various ship models, Reynolds averaged Navier-Stokes computations of the same ships, full scale measurements on board ships at sea and a low-level modeling effort.

It is well known that helicopter rotor blades are susceptible to vertical gusts. Wilmer[1] modeled the effects of gusts on the behavior of rotor blades at low r.p.m. and identified a "cliff-edge" effect which lead to tip deflections of up to 3 ft. on a rotor with a 20 ft. blade radius.

In the current study, we have modeled the large flapping excursions of a H-46 at landing spot 4 on a LHA ship and have compared the results with flapping data extracted from video footage of an actual tip-strike incident. The flapping (including out-of-plane blade bending) and the in-plane rotational degrees of freedom have been modeled. The modeling is based on the following list of observations concerning H-46 tip strikes on LHAs (see Fig. 1):

1.) The LHA has a strong vortex that runs along the ship deck and passes near to a majority of the landing spots. At spot 4, wind tunnel tests show that the core of this vortex is centered approximately at blade rotor height and slightly inboard of the landing spot (see Long et al.[2]). This vortex produces peak swirl velocities approximately equal to that of the wind approaching the ship.

2.) The H-46 rear rotor rotates clockwise (opposite to that of most single rotor helicopters in the U.S.)

3.) The onset of the large flapping excursions occurs on startup and shutdown when the rotor is rotating at approximately 1 rev. per sec.

4.) The rotor overhangs the deck by 3 to 7 ft..

5.) The winds at sea must be other than bow winds for the ship-deck vortex to be created.

6.) Uncontrolled flapping only occurs at low r.p.m. (low centrifugal forces).

7.) Video footage indicates that the blades appear to hit the droop stops during the large flapping motions causing a springboard effect.

tunnel

8.) The rotors on tandem rotor helicopters are known to have aerodynamic effects on each other. Wind test results show that the ship-deck vortex strength is significantly increased downstream of a rotor [2].

Modeling

A computer program has been written that models the out-of-plane flapping (including blade bending) and the in-plane rotor rotational degrees of freedom. The induced-velocity field is modeled using a combination blade-element-vortex-method approach. A vortex (the ship-deck vortex, for instance) can be placed within the velocity field and its effects on the rotor dynamics calculated. Shown in Fig. 2 is the predicted flapping response of a H-46 helicopter blade rotating at 1 rev./sec., subjected to a vortex centered on the hub of strength $\Gamma = 3000$ ft^2/sec. A vortex of this strength produces vertical velocity components of 20 ft/sec at the H-46 rotor tips (representative of that measured in wind tunnel tests of the LHA). In the final version of the paper, blade bending and droop stop impacts will be modeled. In addition plots of the flapping angle and tip deflection time histories will be compared to actual data extracted from a video of a tip-strike incident.

References

1.) Willmer, M. A. P., "The Motion of Helicopter Blades at Low Rotor Speeds in High Winds," ARC C.P. No. 852, 1966.
2.) Long, K.R., Williams, S.L, Bradshaw, P. and Zilliac, G.G., "Flight Deck Airwake Characteristics of US Navy Amphibious Assult Ships: A Comparison of Full Scale, Wind Tunnel, and Math Model Data," AHS Forum 55 , Montreal Canada, May 25-27, 1999.

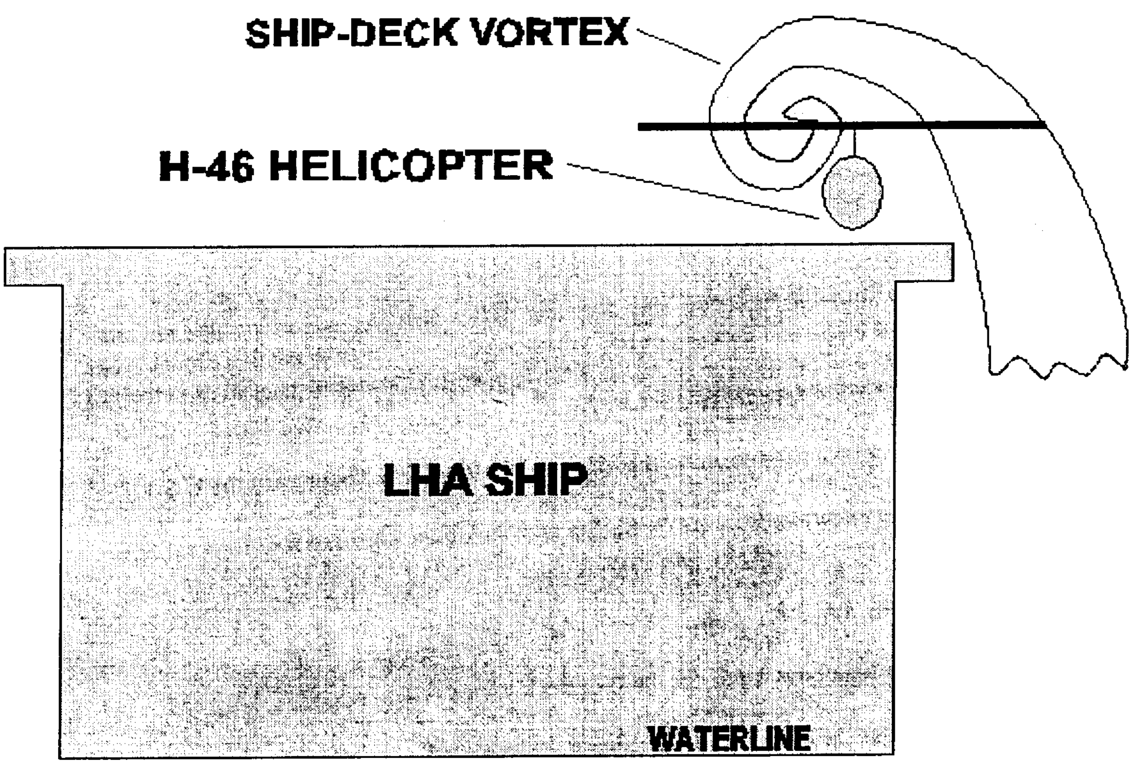

Figure 1. Cross-section of the LHA ship showing approximate location of the ship-deck vortex at landing spot 4.

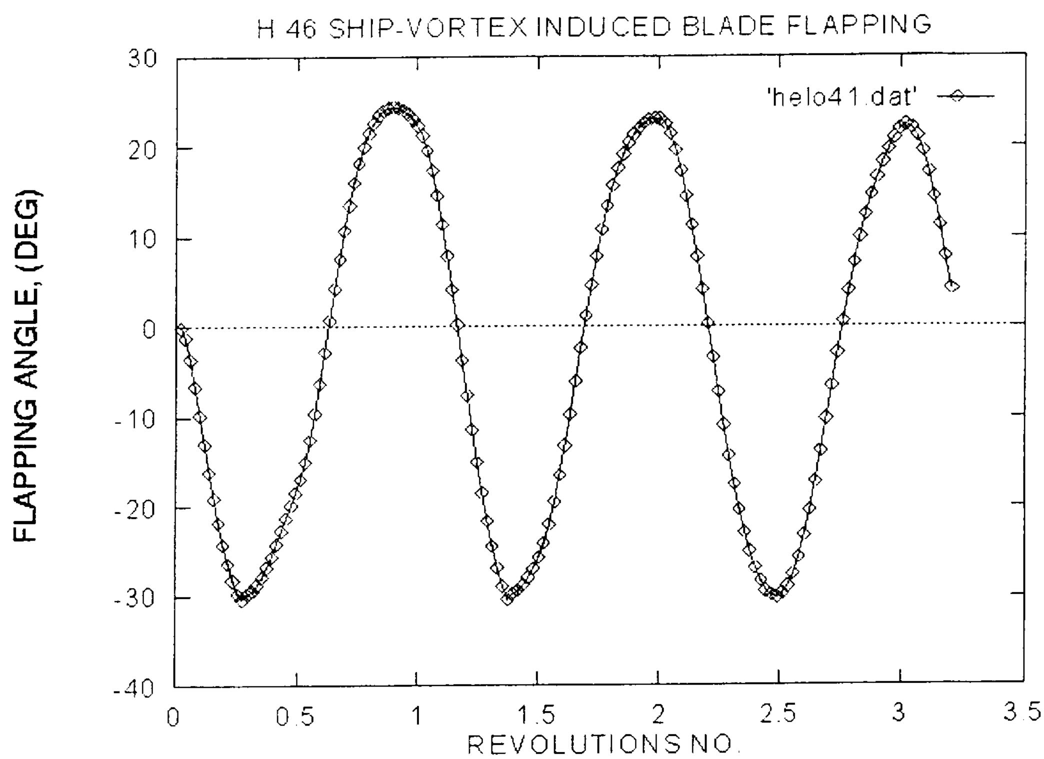

Figure 2. Flapping of an H-46 rotor blade induced by a LHA ship-deck vortex.